METAL HYDRIDE BATTERIES

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Contents

Summary

Material science and technologies on hydrogen storage alloys have been combined with advanced battery technologies to commercialize the Ni-MH battery. The Ni-MH battery is environment-friendly and provides distinguished performances such as high-capacity, high power, long life, high reliability with comparable cost compared with Ni-Cd battery. The battery performance could be changed by material designing, expanding the application field. The high-tech batteries are now the key components in the growing information and telecommunication industries and also in the so-called eco-vehicle industries. The key material of the MH battery is the hydrogen storage alloys.

1. General Background

Most of metals form metalhydrides (MH) by an electrochemical charging process. Usually, the MH are so stable that could not be used as a rechargeable hydrogen electrode, except for palladium. Rechargeable batteries using the Pd electrode was proposed in 1963. The application of a hydrogen storage alloy as the MH electrode was reported for TiNi-Ti_2Ni in 1970 and $LaNi_2$ in 1973 just after discovery of a hydrogen storage alloy. A nickel-MH battery composed of a nickel-hydroxide positive electrode and the MH negative electrode was constructed and evaluated until 1980, bringing very disappointing performances such as short cycle life and poor rate capability due to serious corrosion of the alloys in alkaline solutions.

After the oil crisis of 1974, extensive R&D work on hydrogen storage alloys was focused on gas-phase applications such as hydrogen storage tanks, hydrogen purifiers and chemical heat-pumps. More practical multi-component alloys with long lives were developed based on $LaNi_5$, $MmNi_5$ (Mm: mischmetal), $ZrMn_2$, $TiMn_{1.5}$ etc. by adding other elements such as Cu, Co, Fe, Cr, V, Al, Si etc. Pulverization, which would be a main reason of alloy degradation during cycling, was found to be suppressed by adding Co, Al and Zr for $LaNi_5$.

The cycle of the $LaNi_5$ electrode was improved significantly by adding Co to form the $LaNi_{2.5}Co_{2.5}$ electrode in 1984. It was also found that surface coating of the $LaNi_5$ alloys were very useful to improve the cycle life of sealed Ni-MH cells, suppressing hydrogen evolution during charging. The same effect was obtained by a hot alkaline treatment of the alloys to form a nickel rich surface. First cylindrical Ni-MH battery with high capacity and long life was developed using a alkaline-treated $MmNi_{3.55}Co_{0.75}Al_{0.3}Mn_{0.4}$ electrode in 1988. A sulphonated-polypropylene separator was adopted instead of a conventional polyamide separator in order to suppress a self-discharge. A Cd-free nickel-hydroxide electrode was also developed in 1989. In 1990, commercial production of environmentally friendly Ni-MH battery with twice the energy density compared to the Ni-Cd battery was started in Japan.

Production of small-sized Ni-MH batteries for portable appliances such as cellular phone, lap-top computer, etc. reached 640 millions cells in 1998, comprising 40% of the small rechargeable battery market share, including Ni-Cd and lithium-ion batteries as shown in Figure 1. In 1996, high-performance electric vehicles (EV) using a high capacity Ni-MH batteries were commercialized with twice the driving range compared to a conventional EV using a Pb-acid battery. In 1997, a hybrid electric vehicle (HEV) with an extremely high-powered Ni-MH battery was put onto the market. The HEV market is rapidly growing because it can provide doubled gas mileage and half the CO_2 emission compared to a gasoline vehicle. A highly efficient fuel cell hybrid vehicle (FCHV) with hydrogen tank or methanol-reformer, power-assisted by the Ni-MH battery is under development. Now, the Ni-MH battery is a key component for advanced information and tele-communication systems and also for the next generation vehicles.

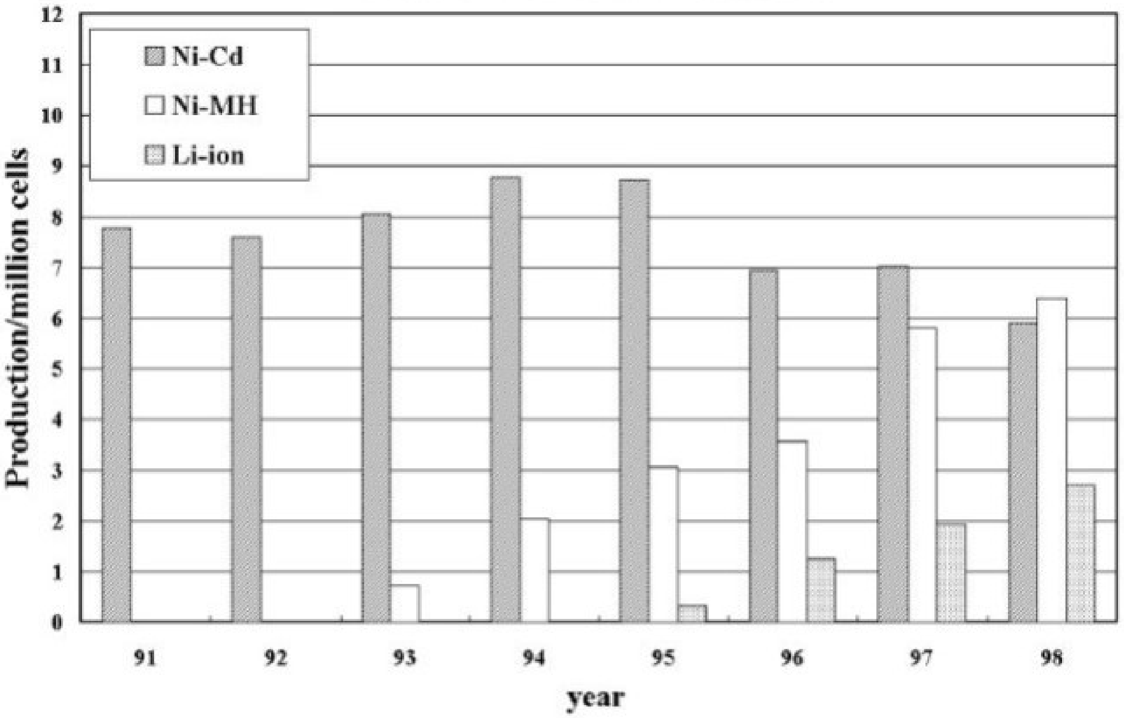

Figure 1. Production of small rechargeable batteries in Japan

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Biographical Sketch

Tetsuo Sakai was born 2 December 1953 in Japan; he received his education from the Department of Applied Chemistry, Faculty of Engineering, Osaka University; received Ph.D. degree in Applied Chemistry from Osaka University in 1982; joined Governmental Industrial Research Institute of Osaka

(GIRIO); devoted to R&D on metalhydride battery; visiting scientist at Stockholm University in 1992–1993; has served as a Visiting Professor of Kobe University since 1998; Head of Battery Section of Osaka National Research Institute (ONRI) since 1998: published 100 scientific reports and papers, 5 books, and 100 patents on the metalhydride batteries.